Technical Change, Capital Formation and Capacity
Unemployment in the United States

by

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Brigitte Selkirk†

Introduction
A critical problem facing our economy today is the rise in long-run "capacity unemployment," defined as the level of unemployment prevailing when the economy operates at capacity. J. Robinson (1978) advanced capital bias in technical change as the explanation for this phenomenon in several industrialized nations since 1970, and particularly since the 1973 oil crisis.

The capital/employment ratio, measured from peak to peak in the U.S. business cycle, has increased steadily in recent years (Selkirk 1978). Accordingly, more capital is needed, not only to permit this steady substitution of capital for labor through time, but also to lower the capacity unemployment rate.

This paper examines the impact of both neutral and capital-using technical change on capacity employment and capacity unemployment, on the basis of a neoclassical production function. The findings, since 1970, are that reduced neutral technical change has boosted capacity employment markedly, and that the increased capital bias in technical change had little impact on capacity unemployment so that faster growth of the capital stock is required to lower the rate of capacity unemployment. If capital accumulation is not sufficiently strong, the available worker hours may have to be shared by a larger number of workers at capacity.

The paper contains four parts. The aggregate neoclassical production function incorporating the impact of neutral and capital-using technical change is presented in Section I. Various levers, notably the utilization rates of labor and capital, are explicitly introduced into the production function, to facilitate the measurement of output and factor requirements at capacity. Using four proxies of capital's utilization rate the stability of estimates of capacity's share is studied. Measures of capacity employment and unemployment are derived in Section II. The impact of capital formation on capacity output and unemployment is derived in Section III, which is followed by conclusions and policy implications.

Estimation of the Aggregate Supply Production Function

Unconstrained estimation of a double-logarithmic aggregate production function with quarterly data yields an estimate of capital's output share that is negative and insignificant (e.g., MacGregor 1976 and Clark 1976), for two reasons. First, compared with employment and hours worked, the capital variable exhibits negligible cyclical fluctuation.

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When real output is regressed on both capital and hours worked, the fluctuations in the latter explain most of the variation in real output, leaving little for the former to explain. Second, multicollinearity of the capital stock and hours worked -- both of which exhibit a growing trend -- increases the variance of the estimates of the parameters, rendering the estimate of capital's share statistically insignificant and (or) reversing its sign.

There are four ways to cope with this estimation problem. First, cyclical fluctuations can be extracted from employment or hours worked. In most aggregate models, output per worker -- a measure of labor productivity -- is used as a dependent variable, rather than output itself. P. Clark (1978) constructed a cyclically adjusted productivity measure for the private nonfarm business sector and regressed this variable on the capital labor ratio, where labor inputs are "capacity adjusted." Long-run productivity growth is thus explained by the capacity-adjusted capital labor ratio. The major problem with Clark's method is that little variation is left in the long-run variables, leading to estimates of the elasticity of labor productivity with respect to the capital labor ratio that are not significantly different from zero at the five percent level. However, the estimates carry the correct sign and their absolute values are plausible. Second, a transformed Cobb-Douglas production function can be estimated by taking account of the ratio of factor shares, computed from long-run statistics on average factor shares. This method was followed by L. Klein and V. Long (1973).

Third, the short- and long-run determinants of productivity can be specified and a reduced form equation estimated. The long-run determinants are based on a modified Cobb-Douglas production function, taking into account technical change of both the neutral and embodied type. Short-run fluctuations in labor productivity are captured by capacity utilization, by the acceleration or deceleration in productivity growth and by expected output growth (Seikawa 1983). Fourth, by multiplying the capital stock (K) with its utilization rate (u), a new explanatory variable, uK is created, which varies over the business cycle to the same degree as employment and hours worked (H). Although this method increases the multicollinearity between K and H -- particularly in models estimated on the basis of quarterly data -- it yields a positive and statistically significant estimate of the capital stock "bias." This method was used by Franke and Tatom (1977) and by Tatom (1980). Although output in Tatom's production function originates in the private nonfarm business sector, the capacity utilization rate in manufacturing serves as a proxy for the capital's utilization rate in a modified Cobb-Douglas production function.

This raises two important questions. First, does the capacity utilization rate in manufacturing adequately measure capital's utilization rate in manufacturing and, second, is a proxy for capital's utilization rate in manufacturing an adequate estimate of capital's utilization rate in the private nonfarm business sector? The first question can be answered affirmatively. Although the Federal Reserve Board conducts surveys of either capacity or its utilization rate in deriving its utilization rate series, capacity indexes are estimated indirectly in a manner that renders them consistent with independently conducted surveys of capacity utilization rates (FRB Bulletin 1976). In related surveys, respondents report on the extent to which "productive capacity" is utilized. This statement relates mainly to their "productive capital stock." The answer to the second question requires empirical tests of the relative success of various estimates of capital's utilization rates in the private nonfarm business sector, which are discussed later in this paper (Table 4).

In this study, the production function is Cobb-Douglas with constant returns to scale and is expressed in natural logarithms. Output (Q) in the private nonfarm business sector is determined by the utilized capital stock (uK) and by hours worked (H). Neutral technical change is a function of time (T) and its altered rate since 1970 is captured by a dummy variable, X. The rise in the capital using bias in technical change is measured by a constant positive bias in capital's share relative to that of labor (X).

The production function can be estimated in the form of either equation 1 or equation 2 below.

\[
\ln Q = \ln n + n'\ln T + n'\ln K + a'\ln (1+X) + (1-e)^2\ln (1+e)\ln H
\]

\[
\ln Q = \ln (1+X) + n'\ln T + a'\ln (1+X) + (1-e)^2\ln (1+e)\ln H
\]

where: \(X = 0\) in 1952a - 1969q
\(X = 1\) in 1970q - 1984q

The Utilization Rate of Capital and Labor.

The average capital output ratio for a complete business cycle, measured from peak to peak, is (K/Q). Capital's utilization rate, \(u\), can then be estimated directly by equation 3 and the resulting estimates are presented in Table 1.

\[
u = (Q/K)/(K/Q)
\]

The mean value of \(u\) at cyclical peaks is 104.7. Severe pressures on productive capacity -- especially on the capital stock -- existed at the peak of 1961q, when \(u\) stood at 104.4.

<table>
<thead>
<tr>
<th>Year</th>
<th>Value of at Cyclical Peaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953q</td>
<td>106.5</td>
</tr>
<tr>
<td>1954q</td>
<td>104.8</td>
</tr>
<tr>
<td>1955q</td>
<td>103.9</td>
</tr>
<tr>
<td>1960q</td>
<td>108.4</td>
</tr>
<tr>
<td>1970q</td>
<td>109.8</td>
</tr>
<tr>
<td>1973q</td>
<td>103.6</td>
</tr>
</tbody>
</table>

The average number of hours per worker at annual rates, measured for a complete peak-to-peak business cycle, is (H/C). This measure has declined steadily from cycle to cycle, reflecting both the shortening of the average workweek and the decreasing overtime per worker during the last three decades (Table 2).

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Hours Per Worker During the Business Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953-55</td>
<td>2.035</td>
</tr>
<tr>
<td>1955-59</td>
<td>2.038</td>
</tr>
<tr>
<td>1960-66</td>
<td>1.990</td>
</tr>
<tr>
<td>1970-73</td>
<td>1.938</td>
</tr>
</tbody>
</table>
TABLE 3
Value of at Cyclical Peaks

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>101.21</td>
</tr>
<tr>
<td>1974</td>
<td>101.59</td>
</tr>
<tr>
<td>1976</td>
<td>100.77</td>
</tr>
<tr>
<td>1978</td>
<td>102.40</td>
</tr>
<tr>
<td>1981</td>
<td>101.48</td>
</tr>
<tr>
<td>Mean</td>
<td>99.00</td>
</tr>
<tr>
<td>SD</td>
<td>10.11</td>
</tr>
</tbody>
</table>

When \((1+\%C)\) is multiplied by actual employment, \(E\), a "normal" or "average" estimate of hours worked results \((\%H)\). The utilization rate of labor, \(u\), is then computed as the ratio of actual to normal hours (Equation 4). The resulting estimates of \(u\) are listed in Table 3.

The highest observed value of labor's utilization rate, \(u\), at a cyclical peak was registered in 1966 at 102.45. This coincides with the timing of the highest value of capital's utilization rate, indicating that severe pressures on overall capacity existed in 1966, leading to an acceleration of inflation.

The production function (Equation 2) is ideally suited for measuring capacity output if \(u\), and \(E\) are set at their capacity values, \(u_0\), and \(E_0\).

\[
\ln Q = \alpha \ln (1+\%L) + (1 - \alpha) \ln u + (1 - \alpha) \ln E_0 - \alpha \ln E \tag{5}
\]

The Estimation of the Production Function.

The production function presented in Equation 1 was estimated directly for the complete period 1952-1964, without shifting shifts in parameters. The estimated equation is

\[
\ln Q = 0.00516 T + 0.10677 \ln L + 0.65705 \ln H 
\]

\[(15.21) \quad (5.03) \quad (8.01) \]

\[R^2 = 0.99 \]

\[D/W = 1.28 \]

All estimates of the parameters are significantly different from zero at the one percent level and the model explains 99 percent of the variation in output in the private nonfarm business sector. Moreover, the estimate of labor's share (0.657) compares favorably both to Tobin's (1966) computation of the mean share of labor in total cost (0.66) during 1947-75, and his estimate of 0.676 derived from annual data. The unconstrained value of the sum of the shares of labor and capital is 0.964, which is not significantly different from unity.

The production function was again estimated in ratio form (Equation 2) and shifts in its parameters were studied. The estimated equation is

\[
\ln Q - \ln H = 0.00628 T - 0.00260 XT + 0.08187(\ln L - \ln H) 
+ 0.2567 \times [1(\ln L + \ln H) - \ln H] 
\]

\[R^2 = 0.99 \]

\[D/W = 2.09 \]

All \(t\)-statistics are significant at one percent or better. The model explains 99 percent of the variation in output per hour worked. The value of capital's share of 0.298168 for 1952-1964 and 0.30715 for 1970-1982 compared favorably with that based on the unconstrained estimation (Equation 6) of 0.30677. Labor's share of 0.71852 in 1952-1964 and 0.69783 in 1970-1982 is somewhat higher than 0.65705, the value obtained in the unconstrained model.

The impact of neutral technical change on labor productivity was only 0.0016 in the 1970-1982 period, down from 0.00182 in the fifties and sixties. A mild capital-using bias in technical change occurred in the seventies relative to the previous two decades. This is shown by the statistically significant increase in the estimate of \(\alpha\), from 0.28148 in 1952-1964 to 0.30715 in 1970-1982. Although the capital-using bias in technical change raised labor productivity, the marked fall in the growth of the capital stock more than offset its impact on productivity growth.

The model indicates that the restoration of productivity growth rates observed in the sixties requires higher growth of the capital stock (here, more net investment in plant and equipment) and more investment in research and development to assure a new wave of strong neutral and, to a lesser extent, embodied technical change. These conclusions are fully in line with the work of Clark (1976), Chisholm (1981), Kendrick (1961 and 1963) and Seldersams (1963), all based on completely different models.

Stability of Capital's Share.

Table 4 shows that the estimates of capital's share, based on different proxies for capital's utilization rate, range from 0.27 to 0.28 and exhibit a high degree of stability from 1952 to 1964. Because the utilization rates of capital (\(u\)) and labor (\(\alpha\)) vary positively with time (although their trough and peak occur in different quarters) can be used as a proxy for \(u\) without markedly changing the value of the estimate of capital's share from that obtained by using other proxies for \(u\). The direct method for estimating \(\phi\) is developed in this paper (\(\phi_3\)) and the FRR's estimate of capital utilization in manufacturing (\(u_3\)) yield values of \(\phi\) that are not significantly different from 0.28 during the 1952-1964 period. However, the shift in capital's share since 1970 is stronger when \(u_3\) is chosen as capital's utilization rate.

The equation based on \(u_3\) is statistically superior to that based on \(u_2\) as the former exhibits a Durbin Watson Statistic of 2.09, suggesting that the problem of autoregressive disturbances of the error term is less severe if \(u_3\) is chosen as capital's utilization rate.

TABLE 4

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1952-1964</td>
<td>(\phi_1)</td>
<td>(\phi_2)</td>
<td>(\phi_3)</td>
<td>(\phi_4)</td>
</tr>
<tr>
<td>1964-1970</td>
<td>(\phi_1)</td>
<td>(\phi_2)</td>
<td>(\phi_3)</td>
<td>(\phi_4)</td>
</tr>
<tr>
<td>1970-1982</td>
<td>(\phi_1)</td>
<td>(\phi_2)</td>
<td>(\phi_3)</td>
<td>(\phi_4)</td>
</tr>
<tr>
<td>1982-1984</td>
<td>(\phi_1)</td>
<td>(\phi_2)</td>
<td>(\phi_3)</td>
<td>(\phi_4)</td>
</tr>
</tbody>
</table>

Dependent Variables: \(\ln Q, \ln H\)

\(u_1, u_2, u_3, u_4\)

Notes: The specification of the above equations is based on Equation 2, with \(X = 0\) in 1952-1964 and \(X = 1\) in 1970-1982. All t-values of the estimates of the parameters are statistically significant at 5 percent or better.

\(u_1, u_2, u_3, u_4\) are the following four proxies for capital's utilization rate.
II. Capacity Employment

Capacity employment cannot be observed directly except at cyclical peaks. In this paper, it is measured by setting variables and parameters in the aggregate production function at their capacity values. A distinction should be made between hours worked at capacity (H*) and the number of workers employed at capacity (E*). H* can be readily obtained from the production function (Equation 3). Capacity output (Q*) is measured by peak-to-peak interpolation of output in the private nonfarm business sector. Capital's utilization rate is set at its capacity value of u* = 106.7, unless u > 106.7, in which case H* = u. The contribution of the fully utilized capital stock is deducted from Q* and hours worked at capacity (H*) are derived by dividing labor's contribution to capacity output by labor's share, (1 - s). These steps are reflected in Equation 8.

\[ H* = \frac{1}{s} (106.7 - n - \frac{e}{106.7}) \]

Capacity employment is then obtained by setting labor's utilization rate, v*, at its capacity value of 101.9 and solving Equation 9.

\[ E* = \frac{H*}{v*} \to \frac{H*}{101.9} \]

The value of v* = 101.9 was chosen as the mean of two peak values, 102.45 (1966Q3) and 101.48 (1975Q1), since 1970Q4 was only a weak peak. The value of H' was equal to 1.99 in 1970Q3 and 1.94 after 1973.

Technical Change and Capacity Employment

Two types of technical change influence capacity employment (E*) in the seventies relative to the previous two decades. While neutral technical change weakened markedly, the capital-using bias in technical change slightly increased since 1970.

Given capacity output γ, a rise in the capacity-using bias of technical change since 1970 clearly lowered capacity employment. Since 1970, capacity employment E* indicates a positive response to changes. In Equation 10, this condition leads to a fall in the estimate of labor's share from 0.719 in the fifties and sixties to 0.699 in the seventies, in response to a rise in the estimate of capital's share from 0.281 to 0.346 in the seventies. Given capacity output γ, capacity employment E* is thus negatively affected by the rise in capital's share (v*) and positively by the fall in labor's share (1 - v*).

Tests performed with Equation 1 indicate the overall impact of the increased capacity-using bias of technical change had a non-linear positive impact on capacity employment E*.

Given capacity output γ, a slowdown in neutral technical change boosts capacity employment for a given capital stock, ceteris paribus. Declining neutral technical change since 1970 has raised capital intensity markedly and fully overshadowed the impact of capital-using technical change.

The impact of both types of technical change on capacity hours H* and employment E* is shown in Figures 1 and 2, respectively. The slowdown in technical change raised capacity employment by 1.699 million workers (2.04 billion hours) in 1970 and accounted for 12.323 million new jobs (23.6 billion hours) in 1980. It is clear why inadequate technical change since 1970 has been blamed predominantly for the late in productivity growth (Kendrick 1940 and Chirnley 1961). It is also the key factor that has boosted capacity employment in the last twelve years.

Total Capacity Unemployment

Capacity unemployment, U, is defined as the residual between the capacity labor force and capacity employment. The civilian labor force (LF), is obtained from peak-to-peak interpolations of the civilian labor force (LF). If RES the peak-to-peak interpolates of the civilian labor force in the other than private nonfarm business sector, total capacity employment E* = RES + E*, while capacity unemployment, U = LF - E*. The capacity unemployment rate, UR, is defined as U* / LF*.

Logc AA in Figure 3 shows the growth in the capacity unemployment rate since 1970. UR climbed from 4.4% in 1970 to 6.4% at the peak of the business cycle in 1978 and further to 6.5% in 1979 peak. This implies that in the last two years of the Carter Administration the actual unemployment rate dropped below the capacity rate, causing inflation to accelerate. UR stood at 6.75% last year, and is still climbing. A strong recovery that lowers the actual unemployment rate below 8 percent in 1984 is bound to trigger a new wave of inflation and to rekindle inflationary expectations.

III. The Impact of Capital Formation on Employment, Unemployment and Capacity Output

Growth of the capital stock in the private nonfarm business sector dropped from an average annual rate of 8.6% in 1955-69 to 7.6% in 1960-72. Therefore, if capital growth had not slowed after 1970, the capital stock would have been $959.6x billion or 2.6% above its actual level in 1982.

The capital/employment ratio, K/E, measured at cyclical peaks, has risen steadily by 7.5% per cent, from $9.63 thousand per worker in 1955Q2 to $13.78 thousand in 1975Q4. The evidence is shown in Table 5. The implications of the increase in K/E are significant.

<table>
<thead>
<tr>
<th>Year</th>
<th>Capital/Resident Ratio at Cyclical Peaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955Q2</td>
<td>9.83</td>
</tr>
<tr>
<td>1955Q4</td>
<td>10.48</td>
</tr>
<tr>
<td>1956Q2</td>
<td>11.89</td>
</tr>
<tr>
<td>1956Q4</td>
<td>13.52</td>
</tr>
<tr>
<td>1975Q1</td>
<td>15.90</td>
</tr>
<tr>
<td>1977Q4</td>
<td>16.70</td>
</tr>
</tbody>
</table>

that more and more capital is needed each year to create new jobs. Increased capital requirements per worker and slower growth of the capital stock are the two prime factors explaining the rise in the capacity employment rate UR since 1970.

Although the K/E ratio increases steadily through time, during the course of either one quarter or even one year, K/E cannot change much as technology and capacity in the capital goods producing industry remain virtually unchanged. Accordingly, it is assumed that peak-to-peak interpolation of K/E yields an annual series of K/E that grows through time, but that is fairly constant each year, despite...
eventual small increments in K and E. The increments to capital, \( \Delta K \), and employment, \( \Delta E \), are added to the stock and on the basis of the capital/employment ratio at capacity \( K/E \), the new capacity level of employment \( K^* \), is obtained

\[
(10) \quad K^* = \frac{E^* + \Delta E}{K^*} = \frac{K + \Delta K}{K/E} \times \frac{K}{E}
\]

or

\[
(11) \quad E^* = \frac{(K + \Delta K)(E/K)}{E + \Delta E}
\]

The increment in capacity employment stemming from the higher growth of the capital stock is shown in Figure 4. Pre-1970 growth of the capital stock would have generated new jobs and markedly more hours worked from 1970 to 1981. Although faster capital formation would have generated some 435 thousand new jobs in 1971, by 1982 not less than 5.8 million new jobs would have become available.

The ratio of hours per worker for each year was computed on the basis of the \( H/E \) ratio computed in Section II. This ratio consists of the product of the average hours worked during each cycle times labor's utilization rate, \( v \), set at its capacity value \( v^* \).

The capacity unemployment rate, \( UR \), increased by 3.5 basis points over a 12-year period; illustrating the huge social cost of a slower growing capital stock. Pre-1970 growth of the capital stock would not only have generated additional employment, \( \Delta E \), but also an "encouraged worker effect," measured by the rise in labor force participation in response to a decline in the deviation of prime age male unemployment from its trend. Accordingly, \( UR \) would have declined from 4.04% in 1970 to 2.24% in 1982. The gain in capacity output -- assuming that average annual capital growth did not decrease since 1970 -- would have been $6.97 billion in 1970 and $13.07 billion in 1982.

If capital stock had experienced faster growth since 1970 capacity employment would have been markedly enhanced. Further, the capacity unemployment rate would have dropped significantly. Finally, capacity output would have been higher. This is consistent with findings by Clark (1978) and Sollekaers (1983) that inadequate capital formation was the prime reason for declining productivity growth since 1970.

Conclusions

The impact of the decline in neutral technical change and the global effect of the increased capital-using bias in technical change raised capacity employment since 1970. However, the growth in the capacity labor force exceeded that of employment, leading to a steady rise in capacity unemployment since 1970.

Although a certain paradox rise in the capital-using bias of technical change since 1970 clearly lowered long-run capacity employment, as predicted by J. Robinson, the concomitant fall in labor's share (1.-1.) due to the constant returns to scale assumption of the aggregate production function raises long-run capacity employment.

Slower growth of capital stock in an economy that needs more and more capital per person per year to create new job openings is the prime reason for the rising capacity unemployment rate. Moreover, various demographic factors (Kendrick, 1981) have been responsible for the marked growth in the capacity labor force and long-run unemployment. The long-run unemployment rate would have stood 2.2 percent below its rate of 6.6 percent in 1982, at pre-1970 capital growth.

Although more capital is clearly needed to create new jobs at capacity, it is unlikely that the aggregate savings rate can be raised adequately to assure this additional flow of investment in plant and equipment. Although investment in research and development, boosting neutral technical change, is a prime factor in restoring productivity growth (Kendrick 1981 and Chinh 1981), it is bound to raise capacity unemployment.

Labor groups may opt for lowering long-run capacity unemployment by recognizing the need to share a limited number of jobs among a larger number of workers and, hence, to shorten the workweek. This is especially important in the U.S. economy, where unemployment compensation is limited to thirteen weeks.

Footnotes

1 Clark introduces an additive binary variable to capture the structural shift in labor productivity growth. A multiplicative binary variable, capturing shifts in both the slope and intercept of the model, would have been more desirable. Moreover, Clark's additive binary variable did not contribute significantly to the explanatory power of the model at the five percent level.

2 This simulation is based on a modified version of equation 3.4 in Sollekaers (1983).

References


